Machinery Messages

Case History

The value of piston rod vibration measurement in reciprocating compressors

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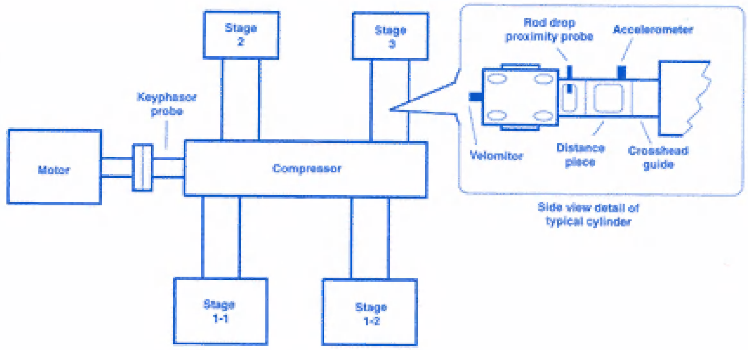

Figure 1
Overall machine layout, showing transducer locations and orientation.

A key part of UNOCAL's Unicracking (hydrocracking) process requires makeup hydrogen to replace hydrogen consumed by the process. This hydrogen is compressed by two hydrogen make-up reciprocating compressors. Each compressor runs continuously to provide 100% of the needed hydrogen. The loss of one of these compressors cuts production in half. Since our hydrocracker unit is a pivotal plant in the refinery, the hydrogen makeup compressors are vital to the refinery's profitability. During the last year, severe reliability problems developed, primarily in the crosshead area and valves, which resulted in reduced availability and lost profit opportunity.

A cross-functional team representing Operations, Maintenance and Equipment Reliability was formed to address the compressor problems. Part of the comprehensive program that was developed was a condition monitoring surveillance program. This consisted of manually recording vibration data twice per month, Pressure Volume electronic analysis every two months and daily walk around inspections. The objective was to develop a set of baseline machine data and determine if vibration analysis could be a viable tool for predictive maintenance. Vibration data came from temporary accelerometers mounted on each distance piece, rod drop probes installed at the packing box on each piston rod, and Velomitor® velocity sensors located on each cylinder head (Figures 1 and 2). The Velomitor sensor is a piezo-velocity sensor with no moving parts. The vibration data was recorded on our Bently Nevada ADRE® for Windows System. ADRE for Windows is an advanced, portable machinery diagnostic instrument. It simultaneously collects vibration data from up to 16 transducers, during

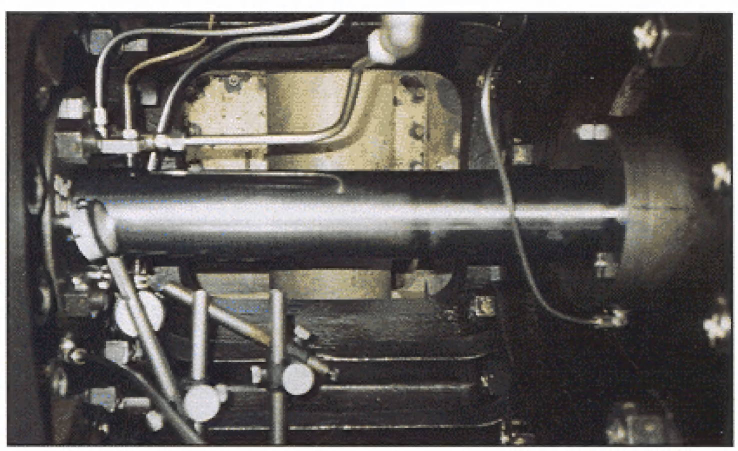

Figure 2
Rod Drop proximity probe installation.

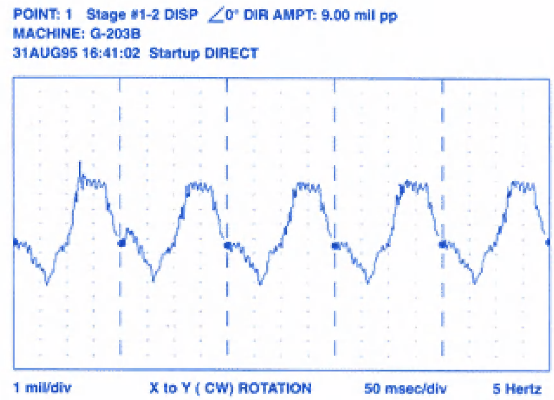

Figure 3
August 31: Rod Drop proximity probe unfiltered waveform, with normal shape.

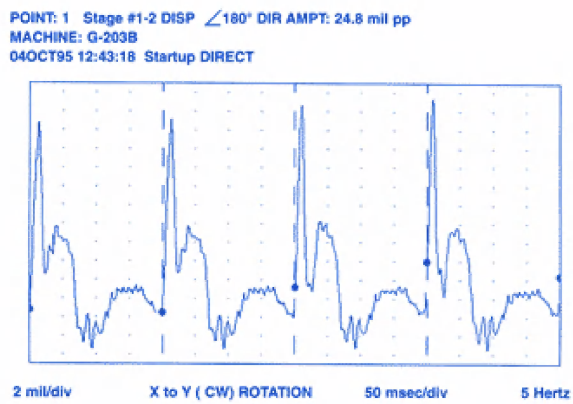

Figure 4
October 4: Rod Drop proximity probe unfiltered waveform. Spikes in the waveform had become more pronounced.

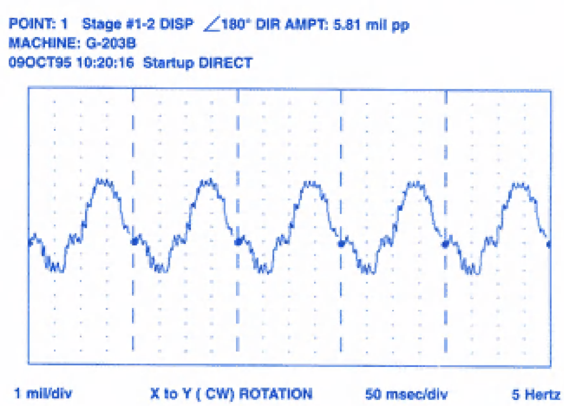

Figure 5
October 9: Rod Drop proximity probe unfiltered waveform. The waveform's shape had returned to normal.

both steady-state operation and during startups and shutdowns. It displays data in many powerful plot formats for accurate problem diagnosis.

Machine Description

The hydrogen makeup reciprocating compressors (Units G203A and G203B) are 375 kW (5000 HP) motor-driven, double-acting, four-cylinder machines that take suction at 1380 kPa (200 psig) and discharge at 11,040 kPa (1600 psig) in three compression stages. As a part of the routine data collection with the ADRE System, piston rod vibration (unfiltered waveforms) was recorded for each cylinder. Typical vibration levels ranged from 152 to 254 µm (6 to 10 mil) pp for all four cylinders.

Data Analysis

Data was gathered on the machines every two to four weeks to assess machine condition. The rod drop vibration waveform from August 31 (Figure 3) was typical. It was sinusoidal with a frequency of 300 cpm, the running speed of the machine.

In early October, a disturbing trend developed on the 1st Stage number 2 cylinder of unit G203B. Comparison of the unfiltered waveform plots from August 31 (Figure 3) and October 4 (Figure 4) indicated that both vibration amplitude and waveform shape had changed significantly. The amplitude started at 229 µm (9 mils) pp and, by October 4, had increased to 630 µm (24.8 mils) pp. The October 4 waveform contained sharp spikes.

There was some concern that the proximity probe might be coming loose, so the access cover on the distance piece was removed and the bracket checked. The probe installation was satisfactory, however, we observed excessive piston rod motion.

Waveform data was analyzed in comparison to the piston motion and Pressure Volume (PV) curves. We used the PV diagrams to calculate rod load (Figure 6) and found that the spike in the waveform occurred at the point of

maximum compressive rod load. This raised the possibility of excessive rod flexure caused by a crack. The increase in piston rod vibration was of sufficient concern that a shutdown and inspection was planned. At the very least, the high rod vibration would cause excessive packing wear.

Inspection results

The primary problem noted was that all four of the piston rings were broken in numerous pieces (Figure 7). In addition, piston rod runout was 152 µm (6.0 mils), due in part to a 63.5 µm (2.5 mil) bow in the rod. The wrist pin bushing clearance was 241 to 254 µm (9.5 to 10 mils), which was slightly out of tolerance — 9 mils was the maximum allowable clearance. Finally, a crankshaft counterweight was improperly seated on the crankshaft. These items were corrected, new piston rings installed, and the unit was put back in service.

Conclusions

Data acquired on October 9 (Figure 5), after the machine was put back in service, shows a vibration amplitude and form that is similar to the data acquired on 31 August (Figure 3). There was no indication of a spike on the waveform, and the vibration amplitude was 148 µm (5.8 mil) pp. Monitoring and trending piston rod vibration proved to be a valuable tool for assessing machine condition. Increased vibration levels were probably due to the breakup of the piston rings and the resulting uneven pressurization in the ring groove. The other problems detected probably would not have caused the observed piston rod vibration. This compressor has had similar piston ring failures in the past. An investigation is under way to determine the root cause of the failure and to design an appropriate ring for this service. In the meantime, piston ring breakup can be indicated by monitoring the piston rod vibration with a Rod Drop proximity probe.

Recently, the waveform data on the first stage number 2 cylinder of Unit G203A showed similar vibration form and amplitude. The machine was shut down, and the piston rings were found to be broken in much the same manner as the G203B machine. This provided further confirmation that piston ring breakup can be indicated by monitoring piston rod vibration.■

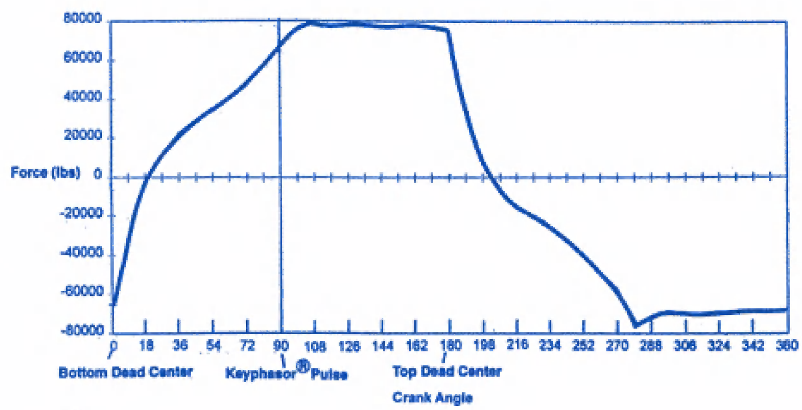

Figure 6

Combined Rod Load in relation to the crank angle.

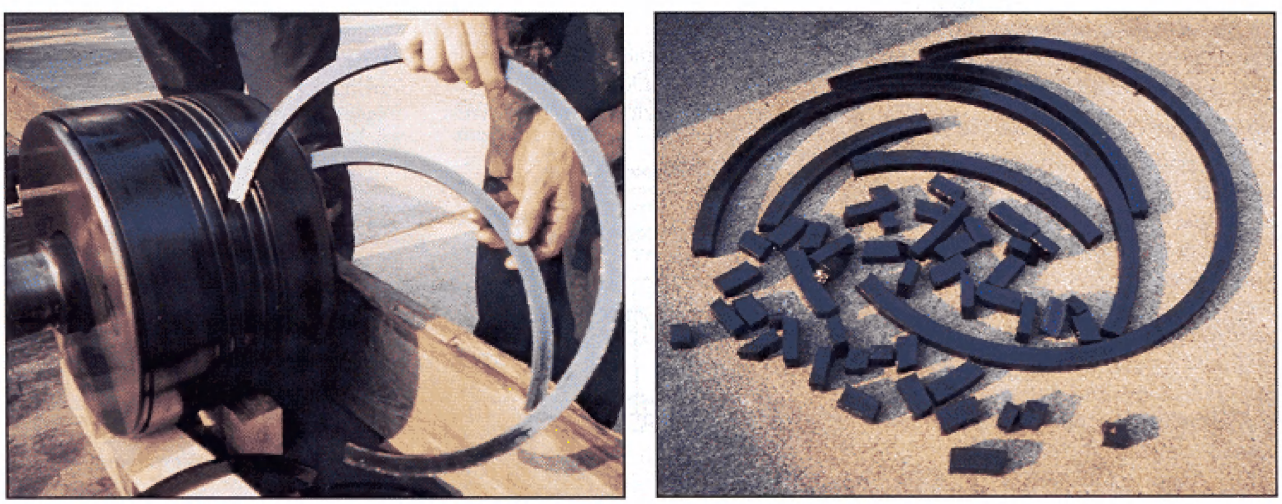

Figure 7

The broken rings that were removed from the 1st stage number 2 cylinder of unit G203B.